Cleanroom Energy Benchmarking

PIER — PUBLIC INTEREST ENERGY RESEARCH — "Research Powers the Future"

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Today's session

Pacific Gas and Electric Company®

- Present selected cleanroom energy benchmarking findings
- Focus on energy efficiency of cleanroom facility systems.
- Case study involving recirculation air setback
- Savings by Design Cleanroom baselines
- What is the audience background?
- What industries/institutions are represented?

Business case - facility system optimization

- Business case for energy efficiency in cleanroom systems - saving energy puts $$ directly to bottom line
- Optimizing facility systems may improve:
  - Energy performance
  - Production (yields) or Research results
  - Maintenance
  - And may *Lower* capital cost
- Some improvements are low or no cost

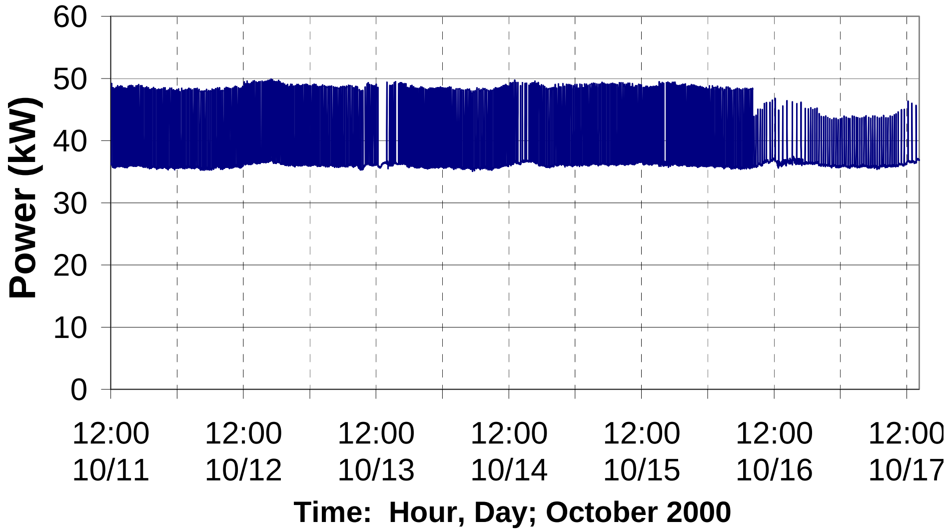
Benchmarking benefits

- Establish Baseline to Track Performance Over Time
- Prioritize Where to Apply Energy Efficiency Improvement Resources
- Identify Maintenance and Operational Problems
- Operational Cost Savings
- Identify Best Practices

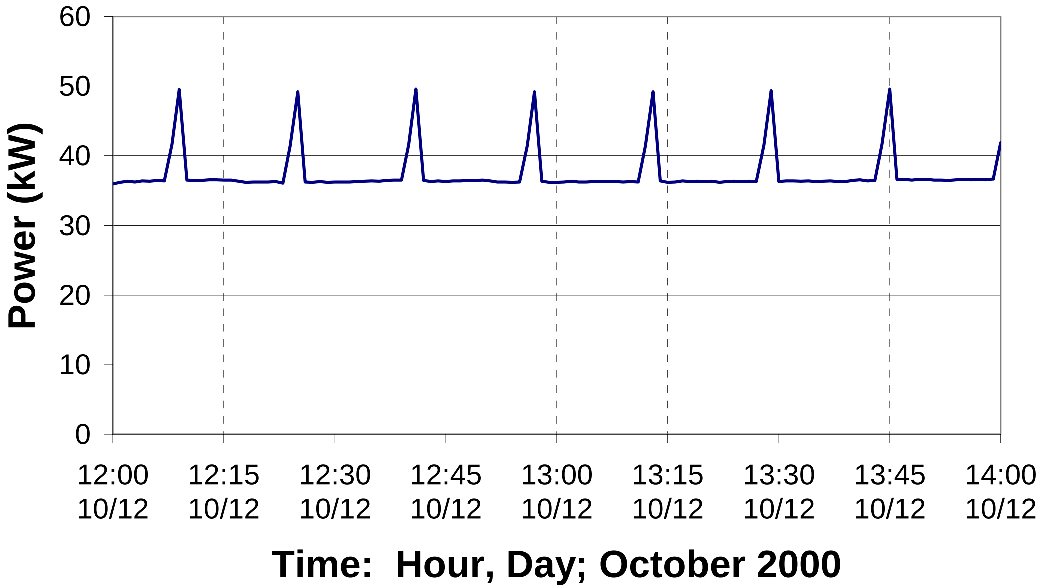
Plus non-energy benefits

- Reliability Improvement
  - Controls
  - Setpoints
- Maintenance identification
  - Leaks
  - Motors, pumps, Fans
  - Filters
  - Chillers, boilers, etc.
- Safety issues uncovered
  - Hazardous air flow

Chilled Water Pump Power



Chilled Water Pump Power



Types of Cleanrooms

- Each cleanroom is unique – but there are common efficiency opportunities
- Many industries and institutions use cleanrooms for a variety of processes
- Many different contamination control schemes
- Many different systems designs

System efficiency vs. production efficiency

- Metrics allow comparison of air system efficiency regardless of process – e.g. cfm/kW or kW/cfm
- Production metrics can mask inefficient systems – e.g. kW/cm^2 (of silicon) or kW/lb of product

LBNL energy benchmarking

Benchmarking Studies available at: http://ateam.lbl.gov/cleanroom/benchmarking/results.html

Energy end-use was determined along with energy efficiency of key systems.

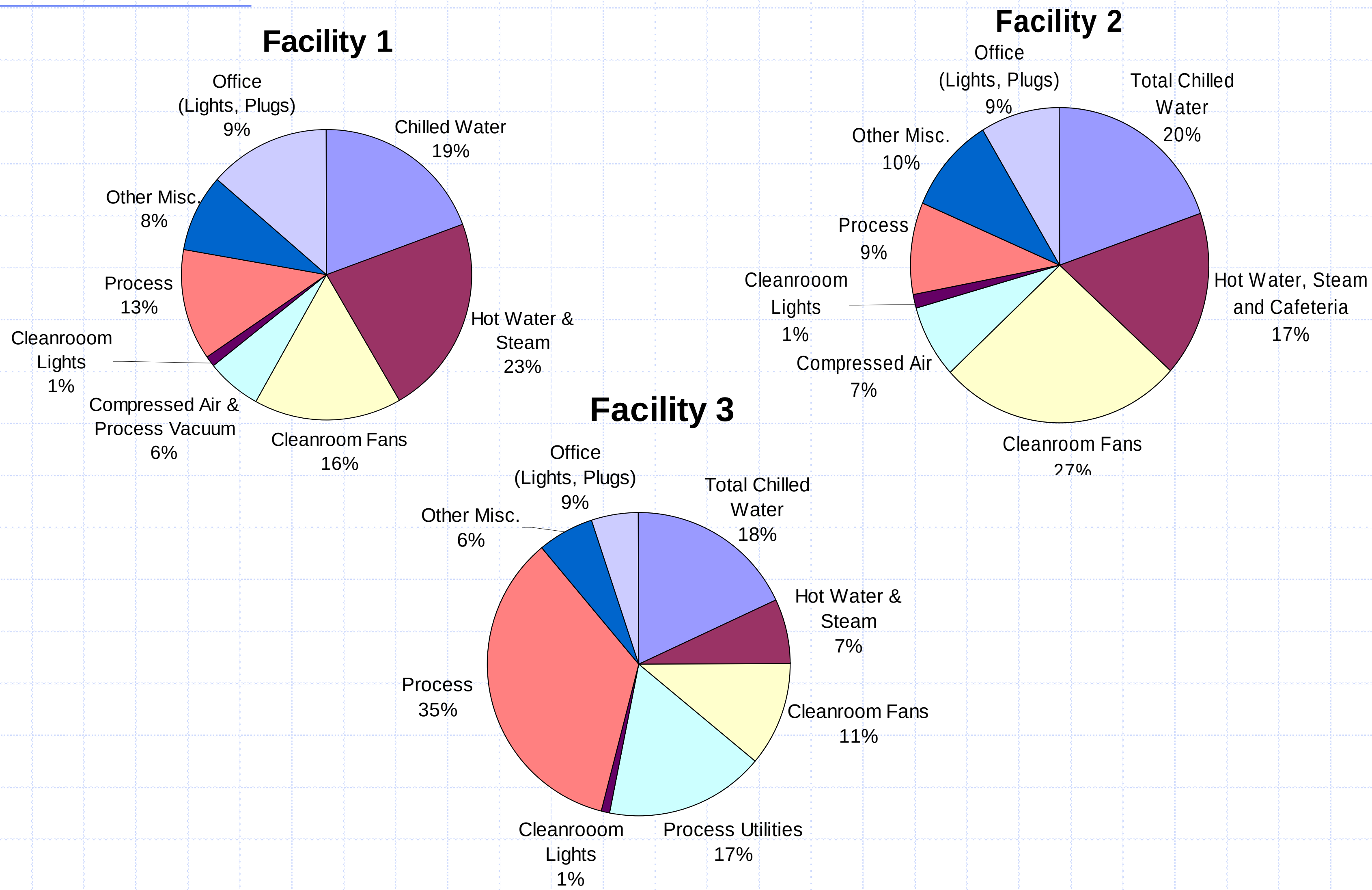
Energy efficiency recommendations were provided to each facility.

Sematech benchmarks

Additional energy benchmarks:

In the mid-ninety's Sematech benchmarked fourteen semiconductor cleanrooms around the world. Similar metrics were obtained although measurement techniques may have differed.

Energy end-use



What are the costs?

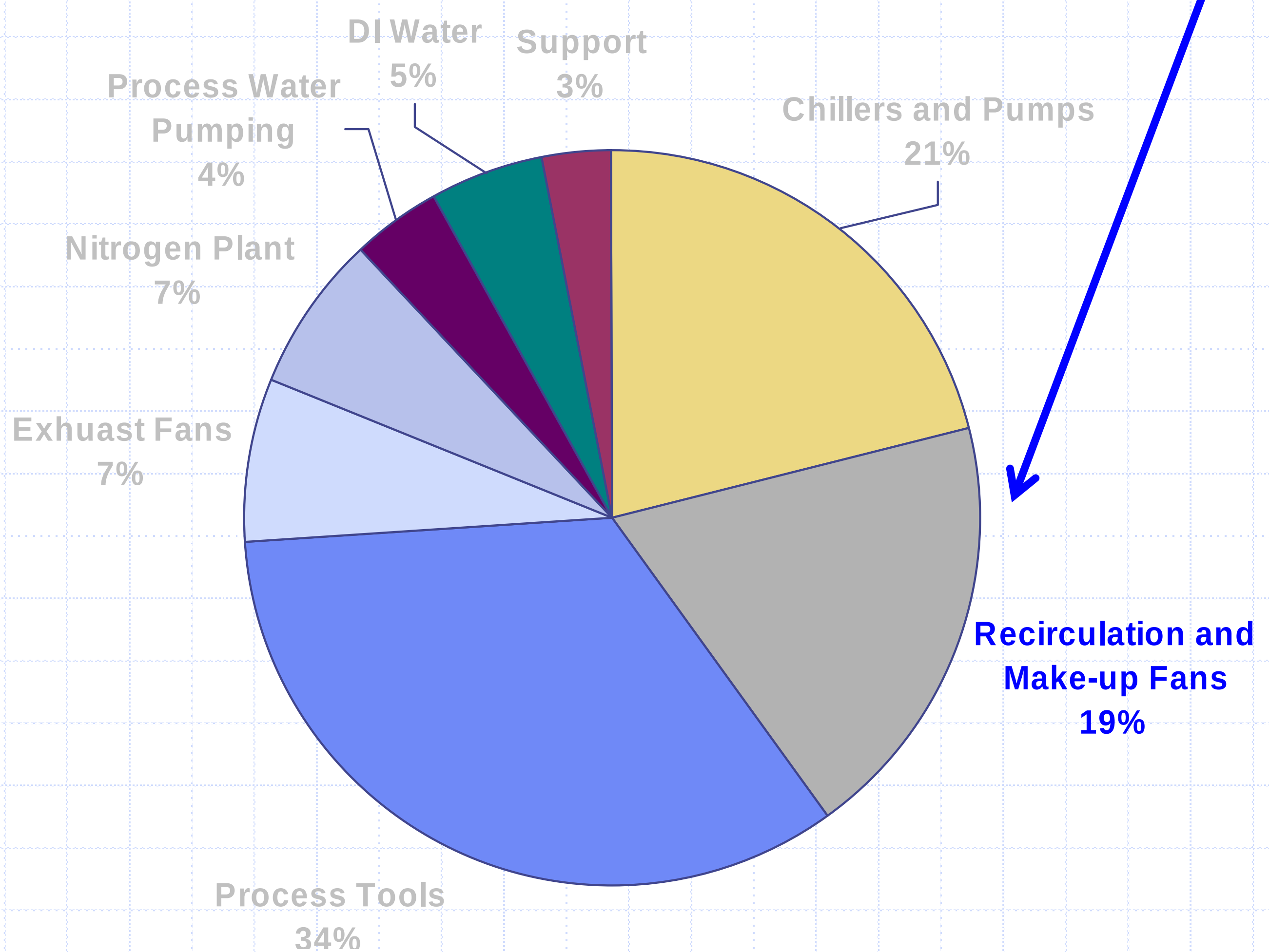
Utility bills from one case study:

Billing days		Dollars
Elec 368	38,084,148 kWh	$2,549,330
Gas 371	70,203 therms	$43,715

approx 20,000 sq ft cleanroom in 68,000 sq ft building w/ $.065 ave. per kW!

Energy intensive systems

air systems in cleanrooms



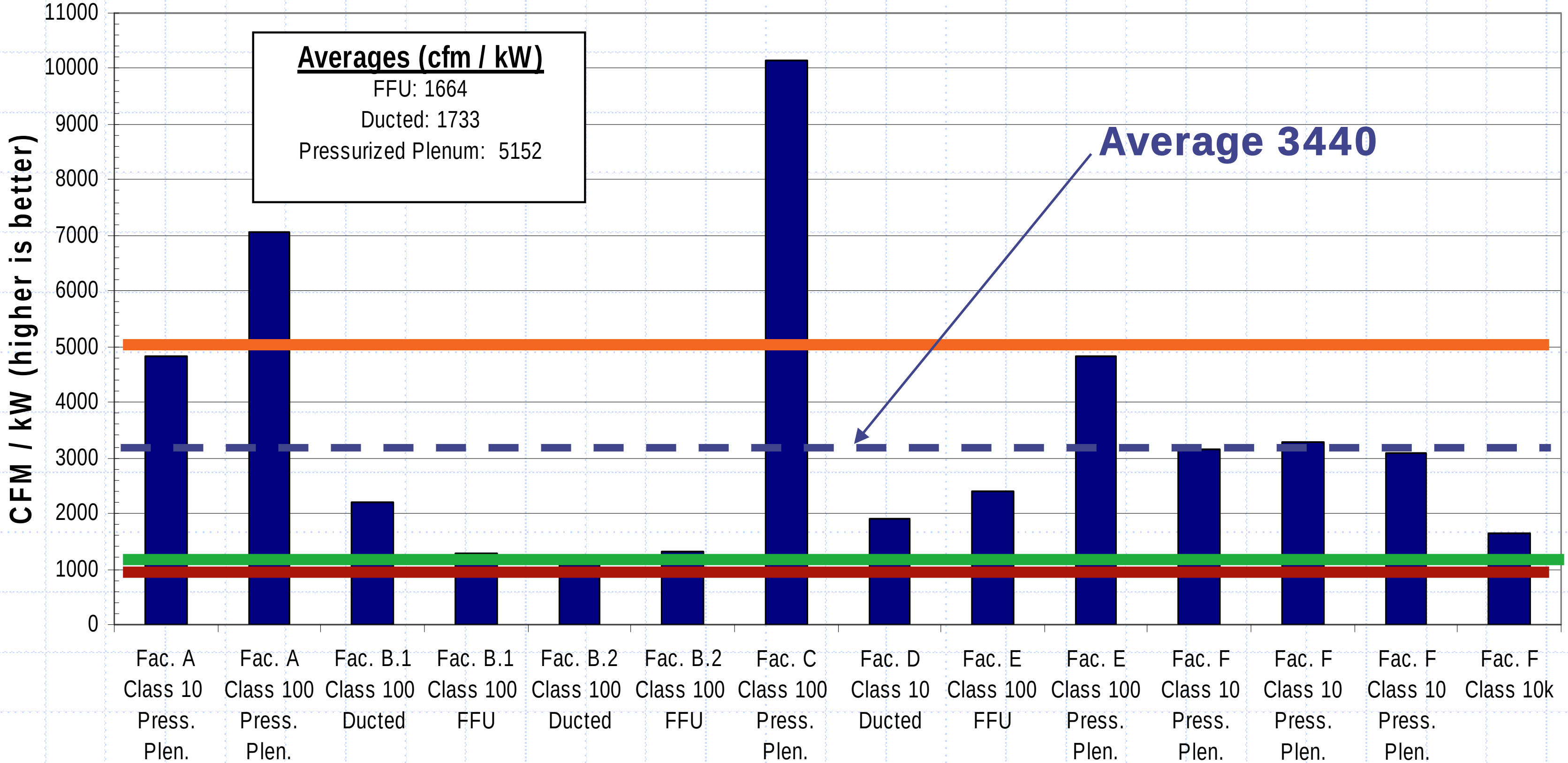
Cleanroom air system metrics

- Air systems – cfm/kW
  - Recirculation
  - Make-up
  - Exhaust

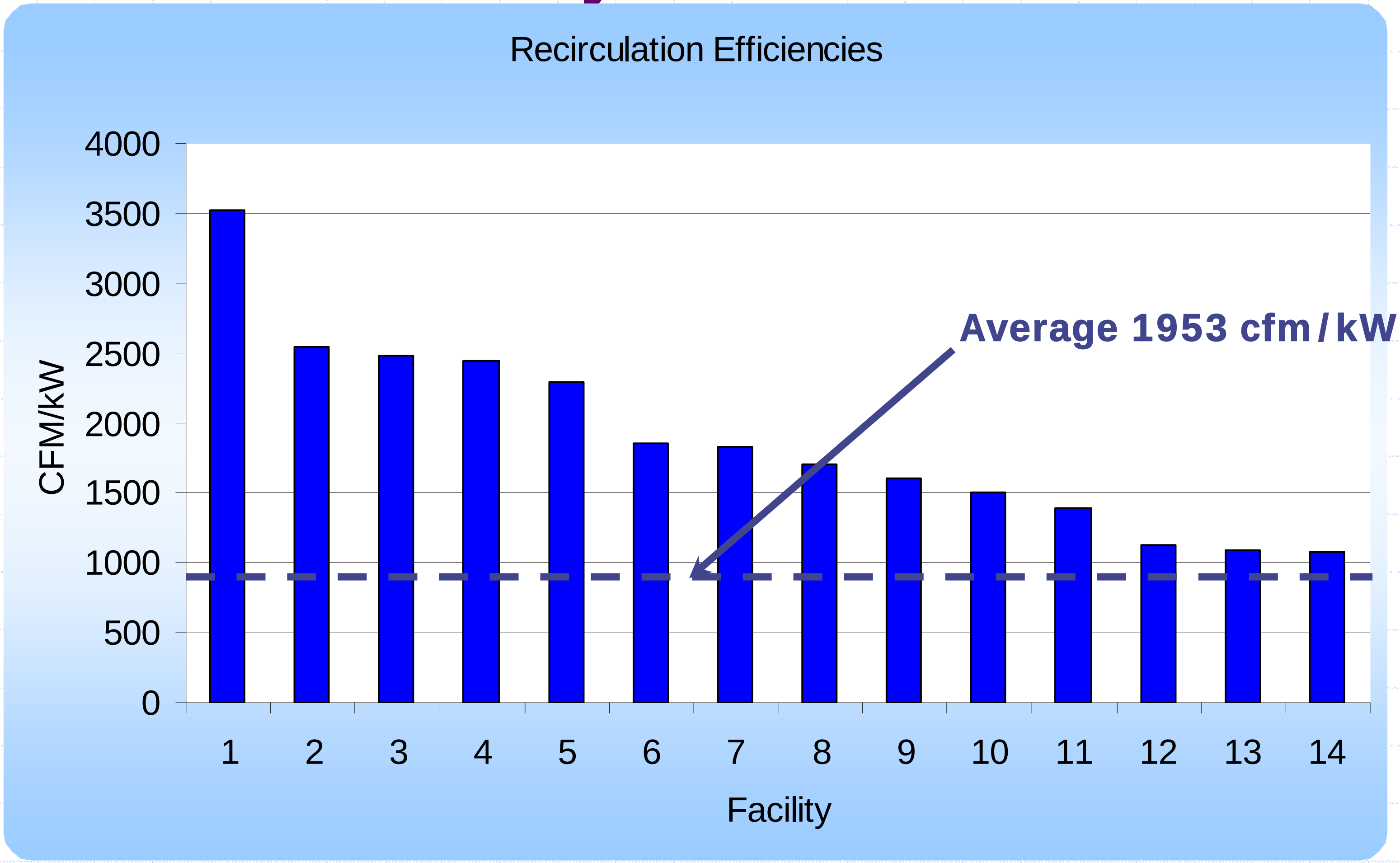
- Cleanroom air changes – ACH/hr
  - Recirculated, filtered air
  - Outside air (Make-up and Exhaust)

- Average room air velocity - ft/sec

Recirculation air comparison



Recirculation efficiency – Sematech study

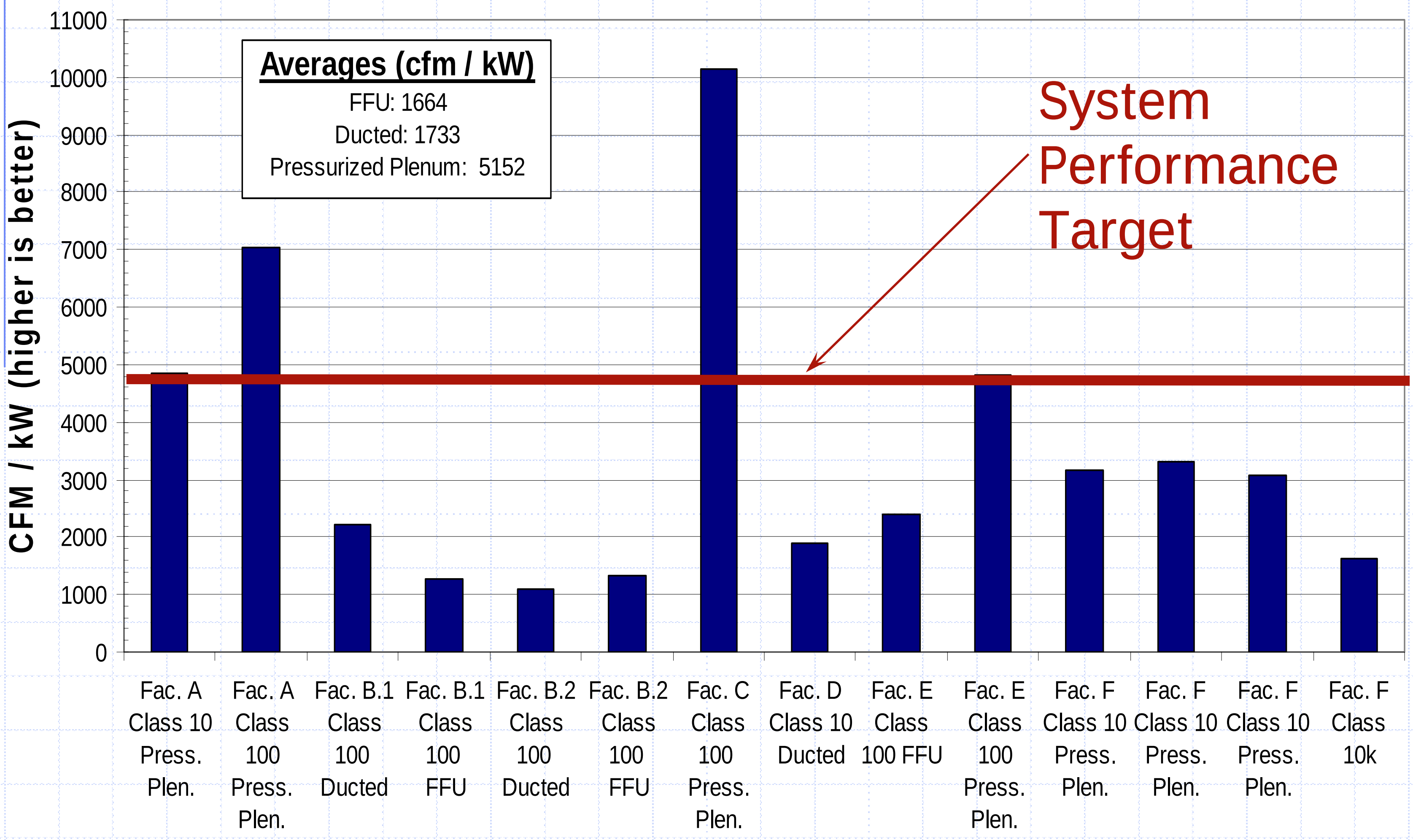


Using benchmarks to set goals

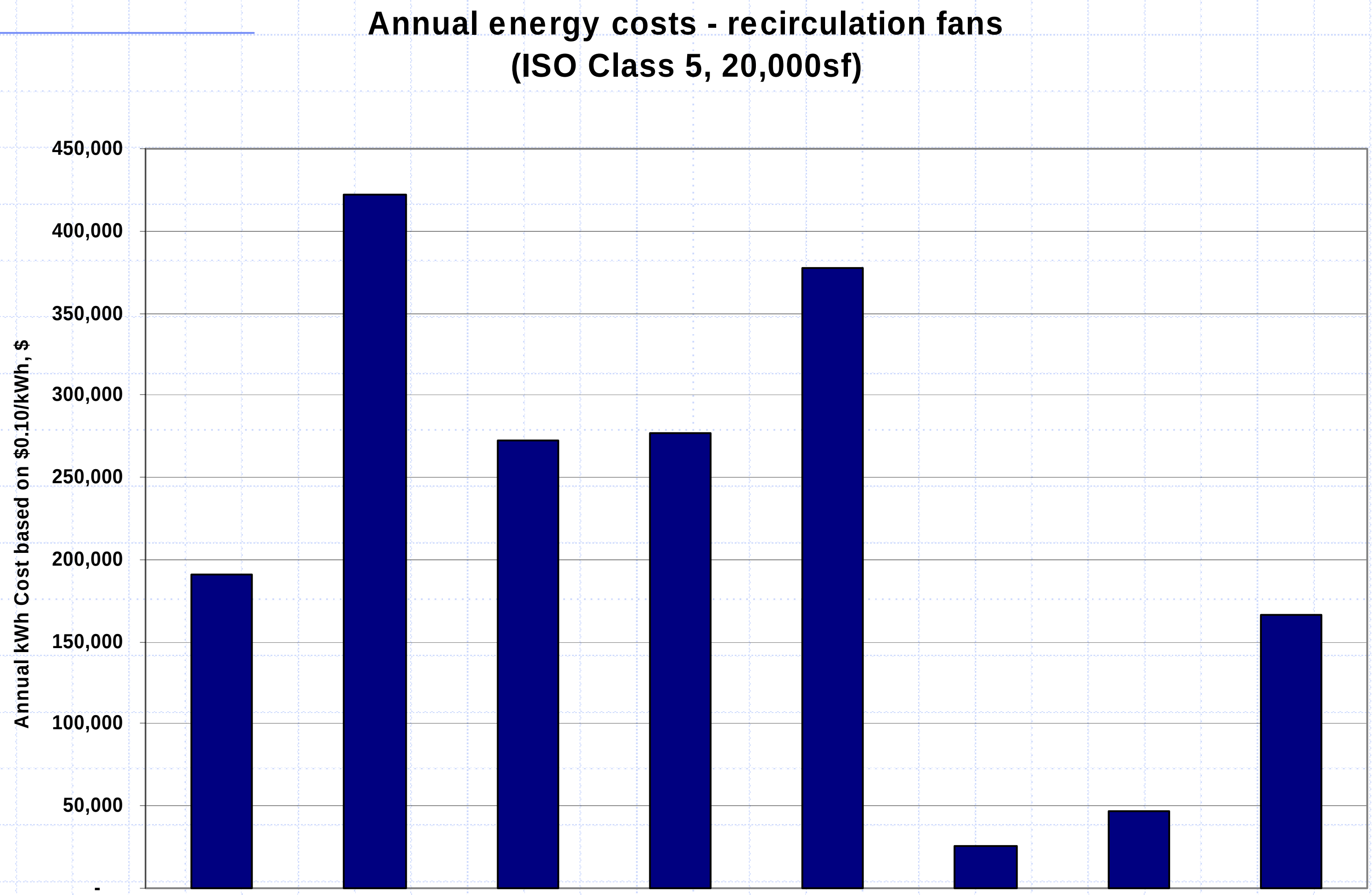
Building Owners and Designers can use benchmark data to set energy efficiency goals.

- **Cfm / KW**
- **KW / ton**
- **System resistance – i.e. Pressure drop**
- **Face velocities**
- **Etc.**

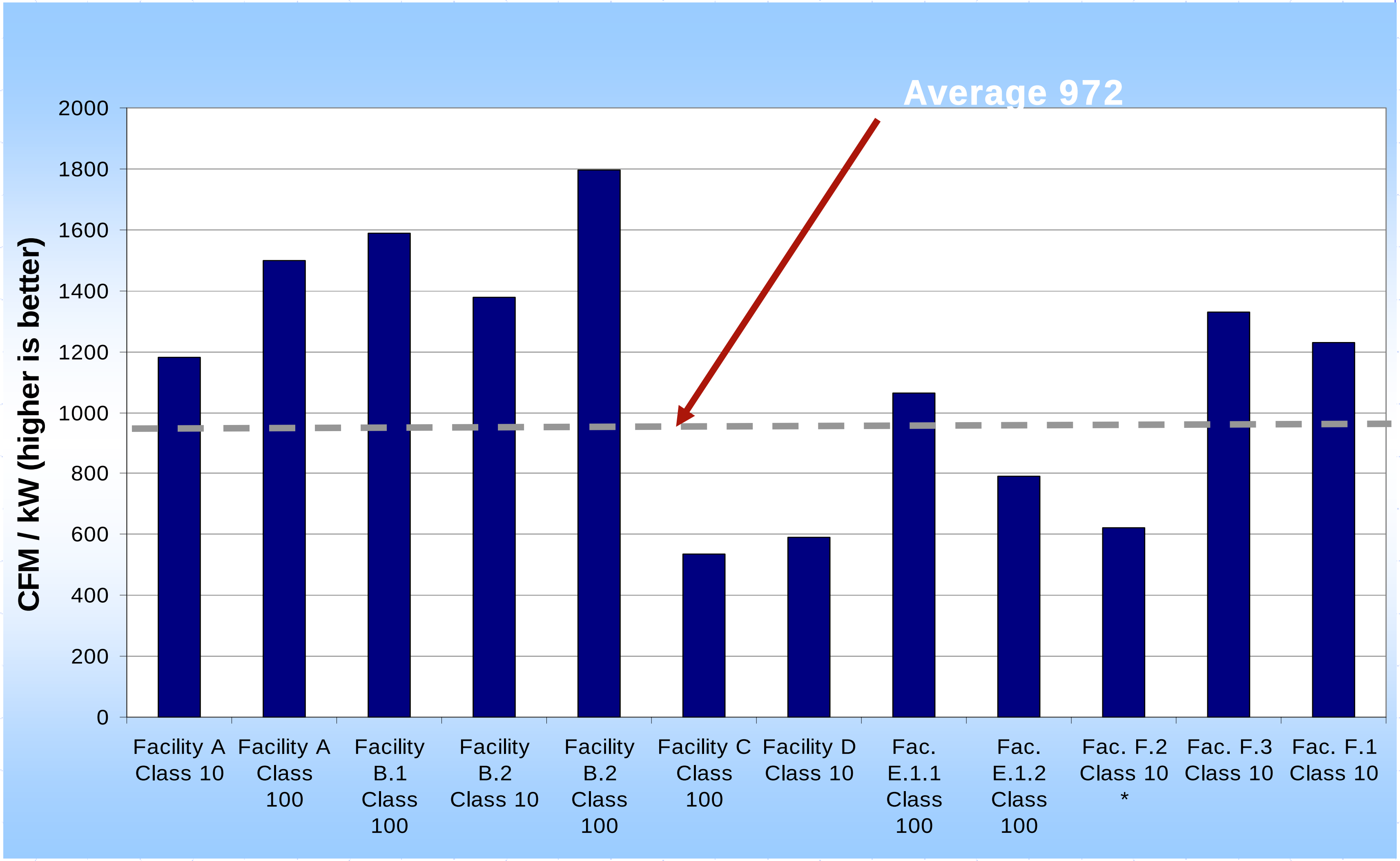
Recirculation air comparison



Hypothetical operating cost comparison

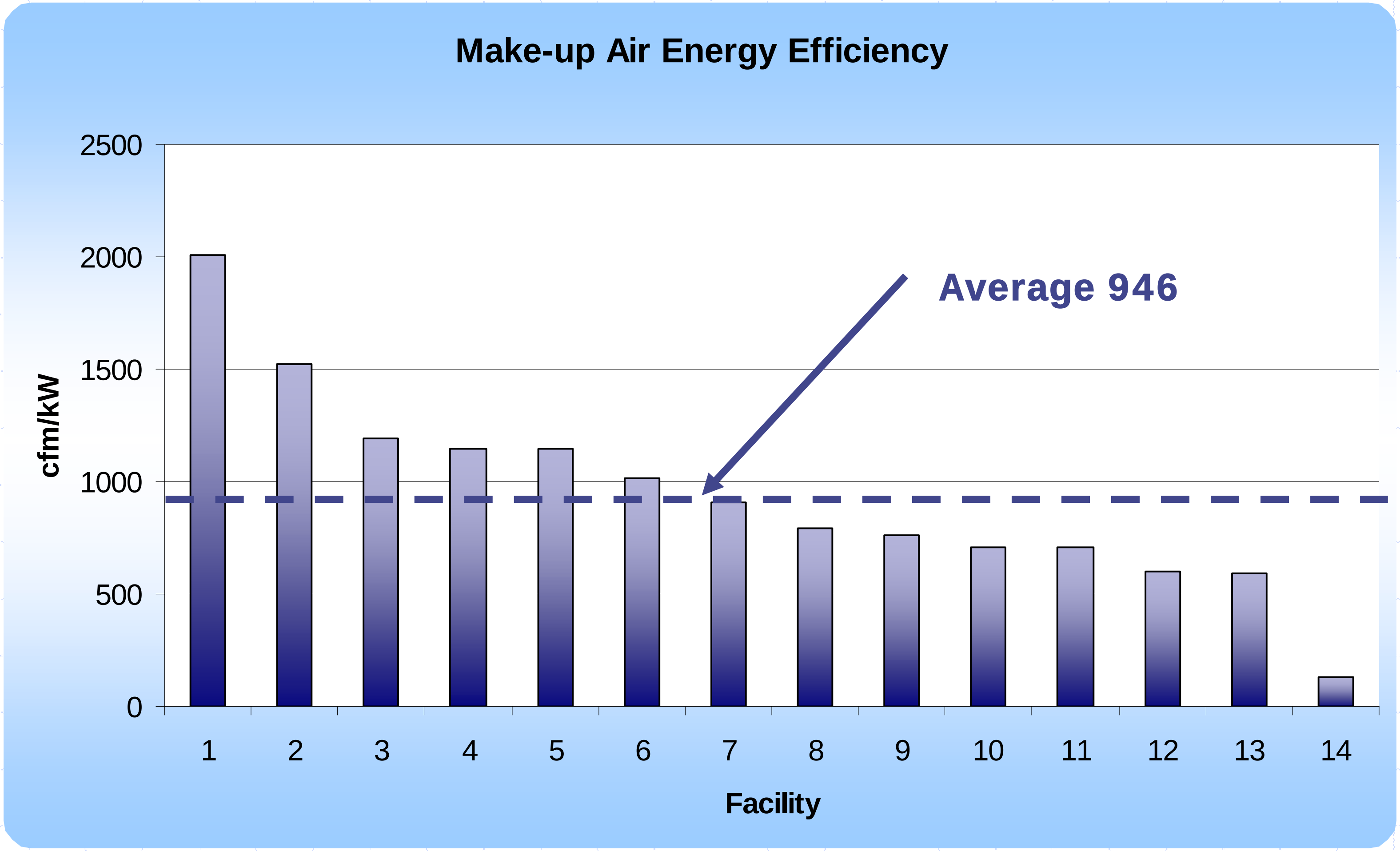


Make-up Air System Comparison



Make-up air system efficiency

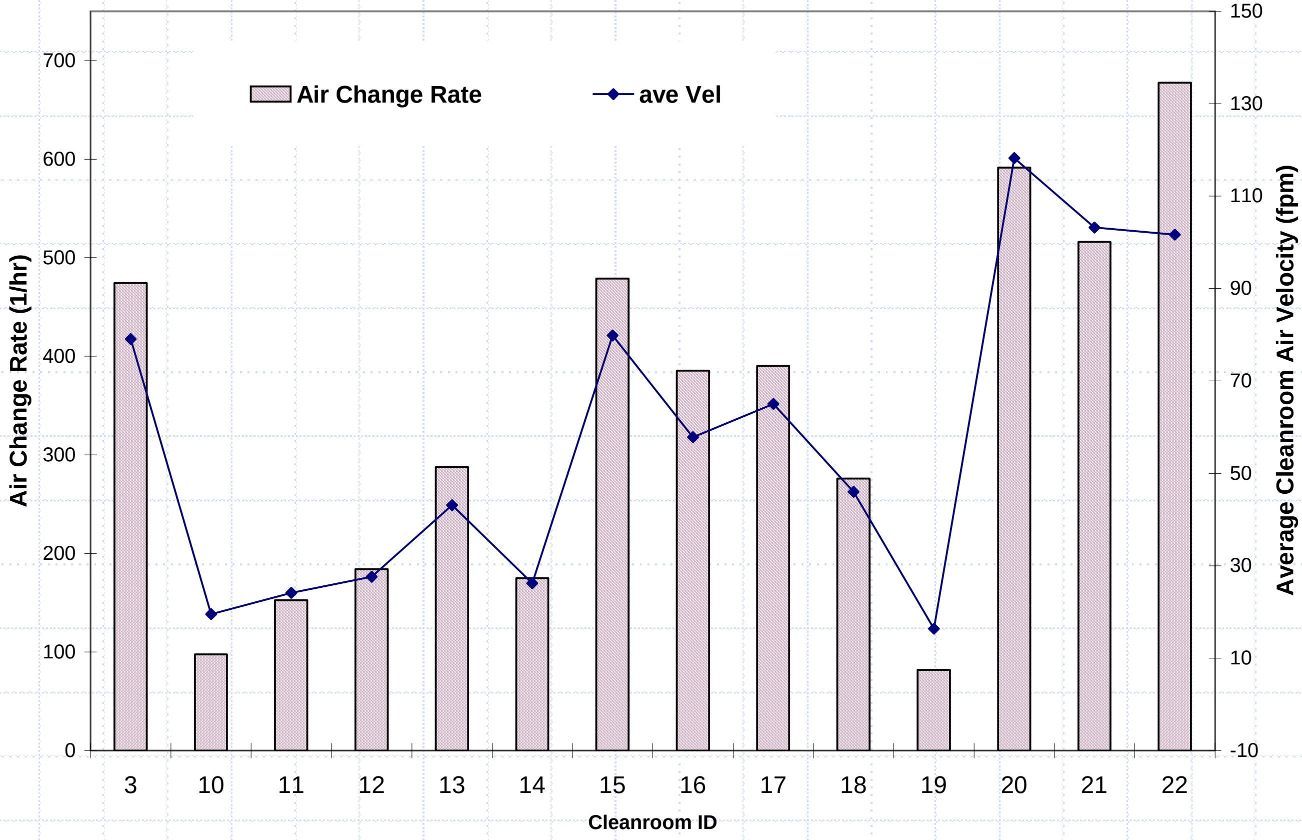
Sematech study



Make-up system efficiency

- Adjacency of air handler(s) to cleanroom
- Resistance of make-up air path
- Pressurization/losses/exhaust
- Air handler face velocity
- Coil Pressure Drop
- Duct/plenum sizing and layout
- Fan and motor efficiency
- Variable Speed Fans

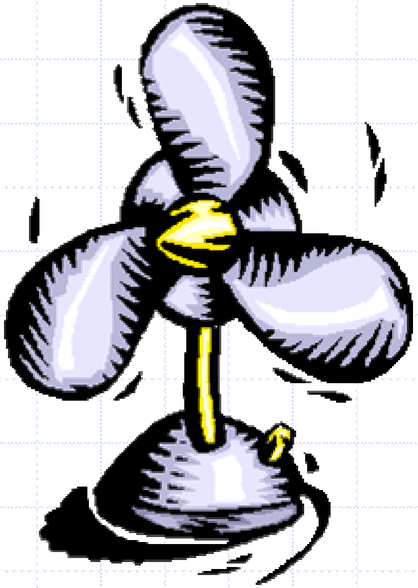
Recirculation air change rates and average velocities



Air-change and velocity choices

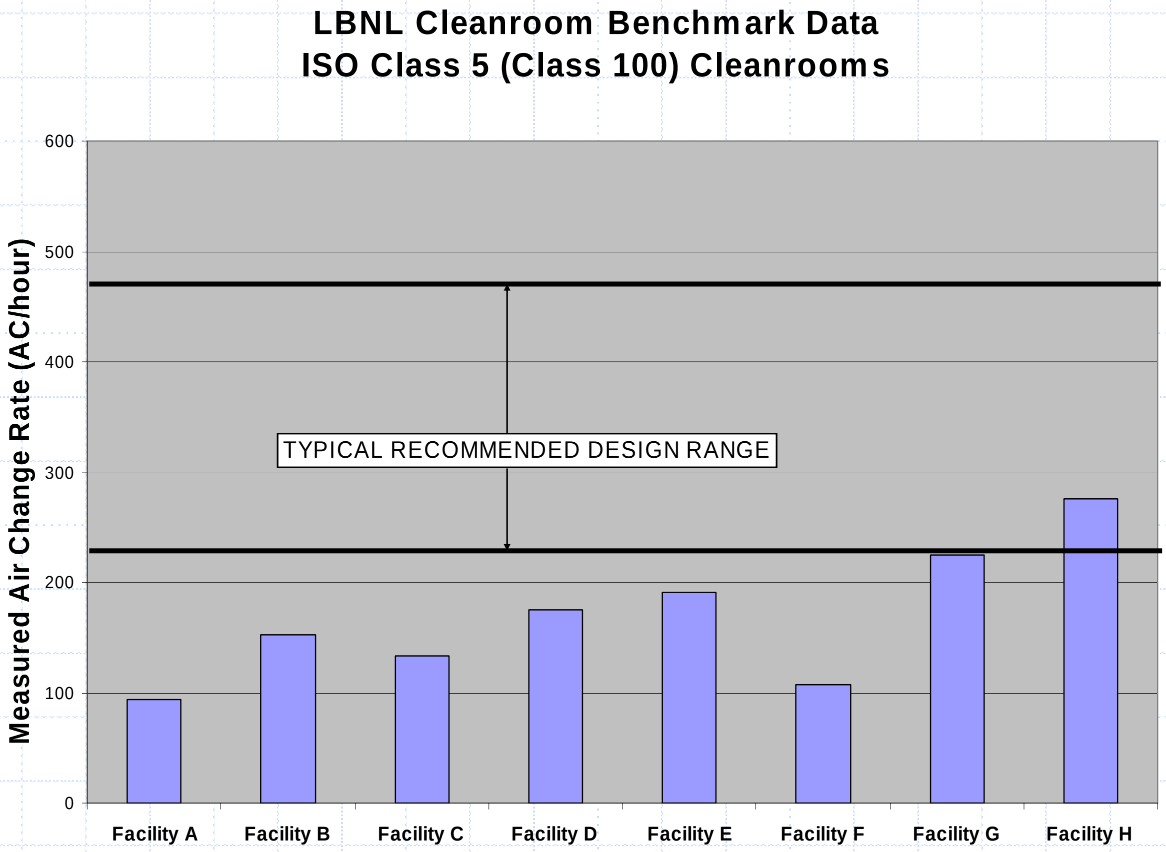
Not an exact science…

- The Institute of Environmental Sciences and Technology (IEST) provides recommended recirculation air-change rates
- Most semiconductor firms have their own criteria
- Studies have shown that more airflow is not necessarily better
- Philosophy of ceiling filter coverage varies
- Pressurization/losses can have a large impact
- Air changes also need to match cleanroom protocol



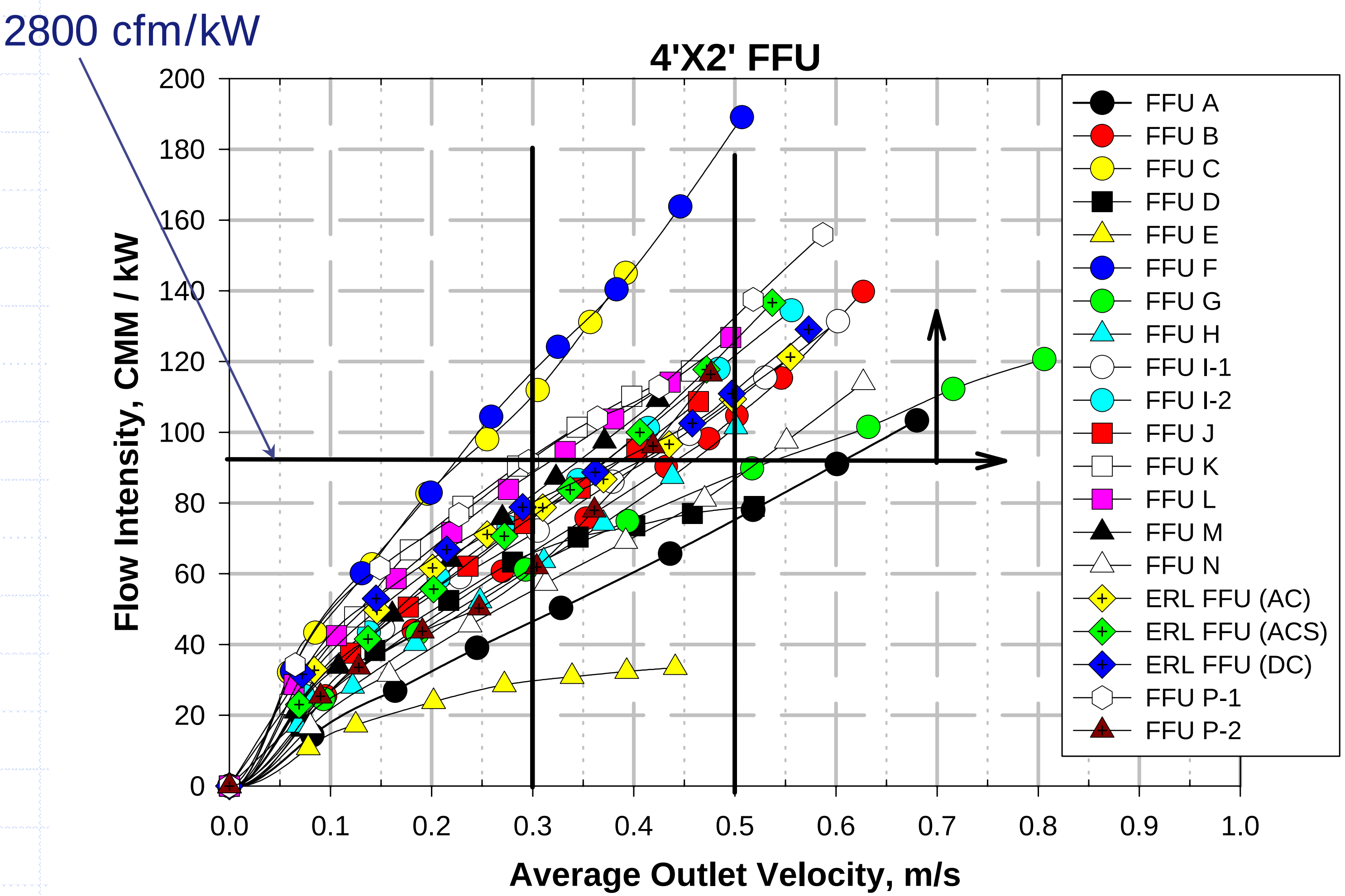
Recirculated air change rates

ISO class 5



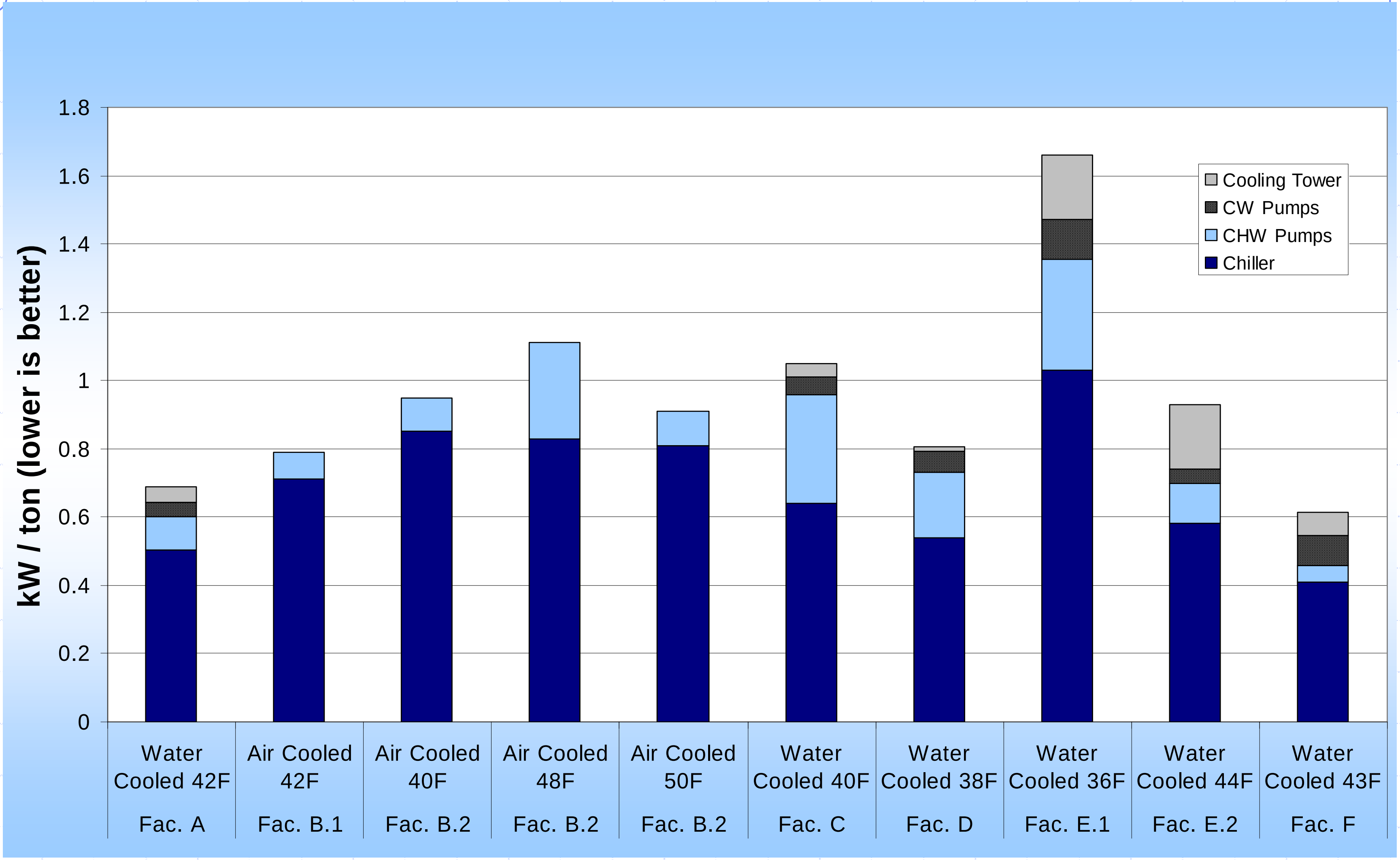
Recommended ranges from Cleanroom Design, second ed., W. Whyte

Component efficiencies also vary

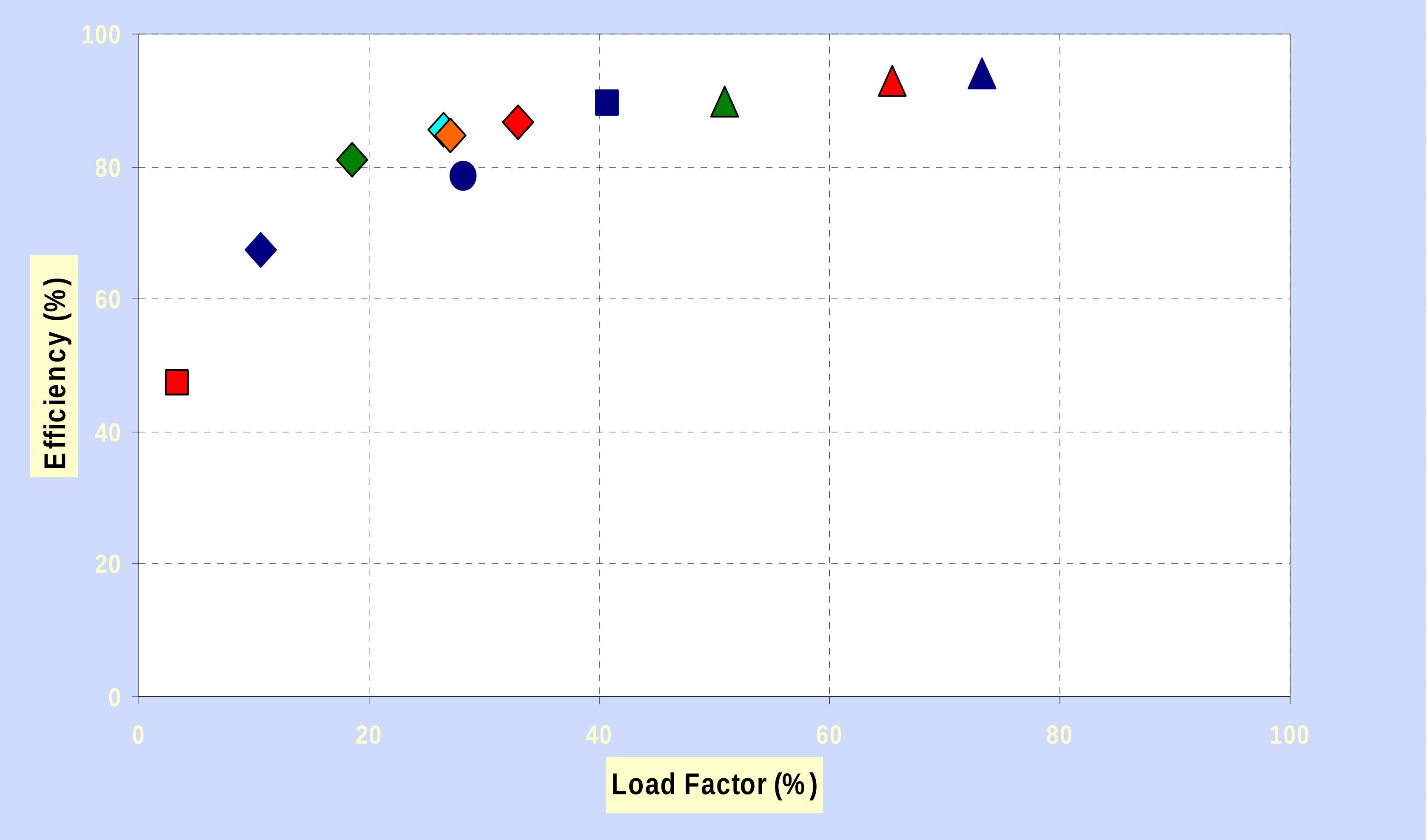


Source: Industrial Technology Research Institute, Taiwan

Chilled Water Systems Efficiencies



UPS Efficiency



Within each system…

Efficiency choices can be made

- System pressure drop – face velocity, duct/pipe velocity, chase sizing, plenums vs. duct, adjacency, layout – changes of direction
- Air change rates
- Ceiling coverage
- Equipment – fans, motors, controls, filters, floor systems

Cleanroom benchmarking highlights some important issues

- Contamination control can often be achieved with reduced air change rates
- Cleanliness ratings are often higher than needed
- Rule of thumb criteria should be examined

  (e.g.: 90ft/min, air changes, filter coverage etc.)
- Overcooling and subsequent reheat can be excessive
- Chilled water pumping is often an opportunity
- Chilled water temperature often is lower than needed
- Many owners don't know how they compare

Best practices/conclusions

- Minimize clean space
- Size for real load
- Correct cleanliness classification for contamination control problem
- Air-change rate can be optimized
- Minimize pressure drop
- Most systems benefit from variable speed devices
- Exhaust minimization

Case study

Good news/Bad news

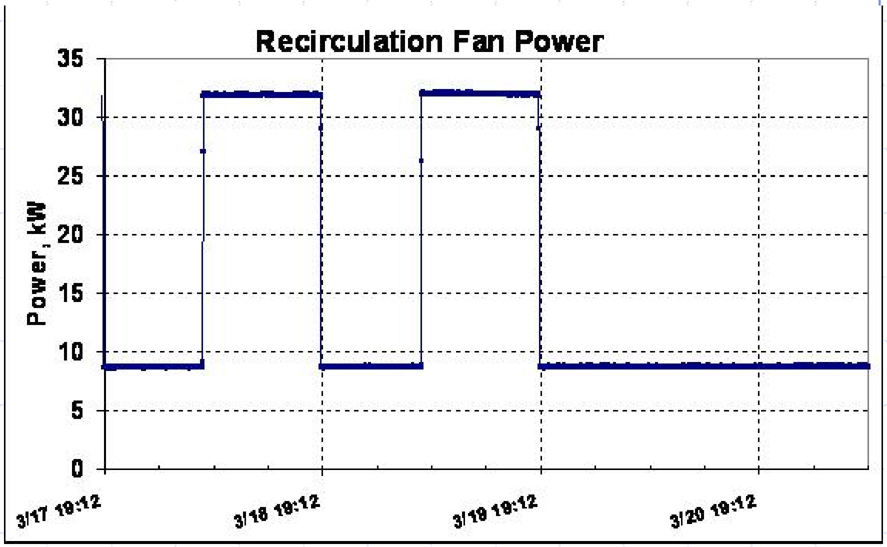
Recirculation setback at night and on weekends was successfully utilized and dramatically saved energy

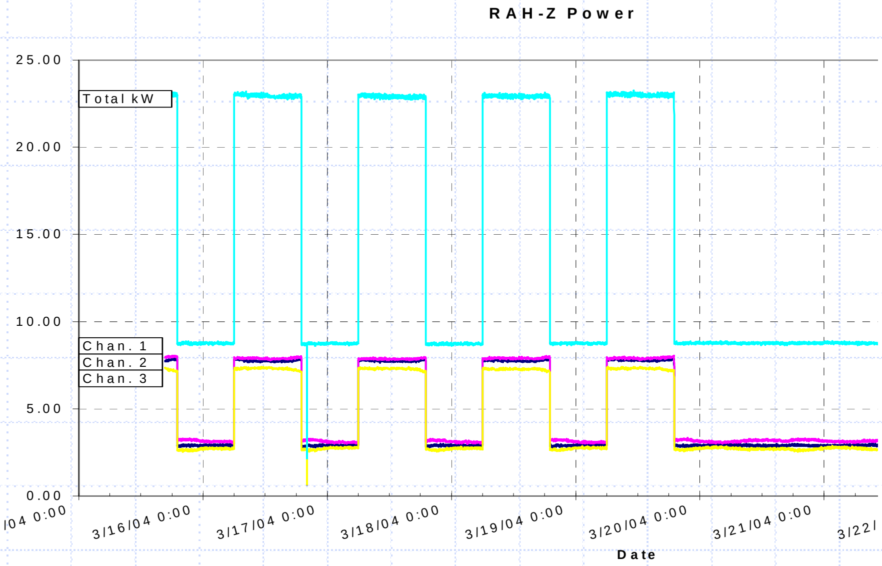
Unfortunately air-change rates were very high and the system had a high pressure drop (resistance to airflow)

Ducting to HEPA filters created more pressure drop

Case study – recirculation setback

- Based Solely on Timeclock, 8:00 PM - 6:00 AM setback
- No reported process problems or concerns from process engineers
- 60% – 70% Power Reduction on turndown





Case study – energy savings

- Annual fan savings from daily and weekend setback:

  1,250,000 kWh
  approximately $138,000

- Cooling load reduction when setback:

  234 kW
  65 tons

ISO 14644-4

Annex F
(informative)

Environmental control of cleanrooms

F.5 Energy conservation

Consideration may be given to incorporating in the design energy conservation considerations, such as provisions to reduce or close down temperature and humidity control and to reduce airflow during periods in which there is no activity. The ability to recover operating conditions in a defined recovery period should be demonstrated.

ISO 14644-4

Annex G
(informative)

Control of air cleanliness

G.4 Energy conservation

For energy conservation reasons, airflow of the ventilation systems may be reduced to low levels during non-operating periods. If, however, they are turned off, the potential for unacceptable room contamination to occur should be considered.

(Its OK to save energy!)

Case study - recommendation

- Air change rates exceeded IEST recommendations during daylight operation.
- Further large reductions in energy use are possible by reducing air change rates and should not affect the process within the room.

Savings By Design

Cleanroom baseline criteria

Recirculation system

- Metric: Watts/cfm
- Determine watts by measurement or from design BHP

$$W = \frac{BHP \times 746}{0.91}$$

- Determine flow from balance report or design documents
- Baseline value is 0.43 W/cfm (2,325 cfm/kW)
- Annual savings=(Baseline - Efficiency metric) x Annual cfm

Savings By Design

Cleanroom baseline criteria

Make-up air system

- Metric: Watts/cfm
- Determine watts by measurement or from design BHP

$$W = \frac{BHP \times 746}{0.91}$$

- Determine flow from balance report or design documents
- Baseline value is 1.04 W/cfm (961 cfm/kW)
- Annual savings=(Baseline - Efficiency metric) x Annual cfm

  where annual cfm = .7 x design cfm
- Run redundant stand-by units in parallel

Savings By Design

Cleanroom baseline criteria

Additional criteria for:

- Chilled water system
- Hot water production
- Compressed air